CLAIMS

What is claimed is:

1. An apparatus for detecting data in a sample sequence read from a recording channel, the apparatus comprising:

an interpolator adapted to generate one or more interpolated sample sequences from the read sample sequence, wherein each interpolated sample sequence has a different corresponding phase relative to the read sample sequence; and

a detector adapted to:

1) generate a distance measure between a portion of each sample sequence and an ideal sample sequence, wherein the ideal sample sequence corresponds to a sample sequence having peaks in the detected data,

2) generate gain error information for the portion of each sample sequence,

3) select either the read sample sequence or one of the interpolated sample sequences based on the minimum distance measures for use in detecting the data, and

4) generating a best gain error metric (GEM) for the selected sample sequence from the corresponding gain error information; and

gain adjustment logic adapted to adjust the read sample sequence based on the GEM.

2. The invention as recited in claim 1, wherein the gain adjustment logic is adapted to generate a gain adjustment value from the GEM.

3. The invention as recited in claim 2, wherein the gain adjustment logic includes a combiner adapted to adjust the read sample sequence based on the gain adjustment value.

4. The invention as recited in claim 1, wherein the GEM is the relative maximum value of gain error information for the portion of each sample sequence.

5. The invention as recited in claim 4, wherein a maximum of the gain error information is selected for a current time, and the maximum of the gain error information is selected for at least one subsequent time for other portions of each sample sequence, and wherein the detector sets the maximum of the gain error information for the current time or the subsequent time as the GEM.

6. The invention as recited in claim 1, wherein the gain adjustment logic is adapted to generate 1) an actual gain error based on the GEM and an ideal gain measure and 2) a gain adjustment value from the actual gain error.

7. The invention as recited in claim 6, wherein the gain logic generates the gain adjustment value based on a comparison of the actual gain error with i) an upper bound and ii) a lower bound.

8. The invention as recited in claim 6, wherein the gain logic generates the gain adjustment value based on the comparison of the actual gain error so as to adjust the gain adjustment value in discrete steps.

9. The invention as recited in claim 1, wherein the gain error information is the sum of the magnitudes of the samples corresponding to peaks in the detected data.

10. The invention as recited in claim 9, wherein the gain error information, $gi_m(k)$, at time k for the mth phase, τ_m, of sample sequence accounting for all B peaks spaced S_bT apart, S_b a positive integer, is:

$$gi_m(k) = \sum_{b=0}^{B-1} \left| y\left(kT + \tau_m - S_bTb\right) \right|,$$

where $|\bullet|$ indicates "the absolute value of "$\bullet$".

11. The invention as recited in claim 1, wherein the data is servo data including an address mark and encoded data.

12. The invention as recited in claim 11, wherein the address mark is a repeatable run out (RRO) address mark and encoded data is encoded RRO data.

13. The invention as recited in claim 1, wherein the distance measure is an absolute value distance between the portion of each sample sequence and an ideal sample sequence.

14. The invention as recited in claim 13, wherein the detector is adapted to determine the minimum of the summed absolute value distance between the portion of each sample sequence and an ideal sample sequence.

15. The invention as recited in claim 14, wherein the detector determines the minimum of the summed absolute value distance $da_m(k)$ at time k as:

$$\min_{m,k} da_m(k) = \min_{m,k} \sum_{b=0}^{B-1} \left| y\left(kT + \tau_m - S_bTb\right) - \hat{y}\left(kT - S_bTb\right) \right|$$

where $y(\bullet)$ is either an observed sample or an interpolated sample, $\hat{y}(\bullet)$ is an ideal sample, B is a positive

integer corresponding to a number of peaks, T is a symbol period, S_b is a separation of the bth peak sample from the prior peak sample ($0 \leq b \leq B$), and τ_m is a phase of either the read sample sequence or one of the interpolated sample sequences (m an integer, $0 \leq m \leq M$, and M a positive integer corresponding to the number of sample sequences).

16. The invention as recited in claim 13, wherein the detector is further adapted to select the minimum of the summed absolute value distance when the minimum is less than a threshold value.

17. The invention as recited in claim 16, wherein the ML detector selects either the minimum of the summed absolute value distance for a current time k or for a previous time k-1.

18. The invention as recited in claim 16, wherein the threshold value is selected based on a probability of error of detection.

19. The invention as recited in claim 1, wherein the distance measure is a minimum distance.

20. The invention as recited in claim 19, wherein the minimum distance is either minimum squared Euclidean distance or minimum absolute value distance.

21. The invention as recited in claim 1, wherein the apparatus is embodied in an integrated circuit.

22. The invention as recited in claim 1, wherein the apparatus is implemented in a read channel component of either a magnetic recording system or an optical recording system.

23. A method of detecting data in a sample sequence read from a recording channel comprising the steps of:

(a) generating one or more interpolated sample sequences from the read sample sequence, wherein each interpolated sample sequence has a different corresponding phase relative to the read sample sequence;

(b) generating a distance measure between a portion of each sample sequence and an ideal sample sequence, wherein the ideal sample sequence corresponds to peaks in the data;

(c) generating gain error information for the portion of each sample sequence;

(d) selecting either the read sample sequence or one of the interpolated sample sequences based on the minimum distance measures for use in detecting the data;

(e) generating a gain error metric (GEM) for the selected sample sequence from the corresponding gain error information; and

(f) adjusting the read sample sequence based on the GEM.

24. The invention as recited in claim 23, wherein step (e) generates a gain adjustment value from the GEM.

25. The invention as recited in claim 24, wherein step (f) adjusts the read sample sequence based on the gain adjustment value.

26. The invention as recited in claim 23, wherein the GEM is the relative maximum value of gain error information for the portion of each sample sequence.

27. The invention as recited in claim 26, comprising the steps of selecting a maximum of the gain error information for a current time, selecting the maximum of the gain error information for at least one subsequent time for other portions of each sample sequence, and setting the maximum of the gain error information for the current time or the subsequent time as the GEM.

28. The invention as recited in claim 23, wherein step (e) comprises the steps of generating 1) an actual gain error based on the GEM and an ideal gain measure and 2) a gain adjustment value from the actual gain error.

29. The invention as recited in claim 28, wherein, for step (e), the gain adjustment value is generated by the step of comparing the actual gain error with i) an upper bound and ii) a lower bound.

30. The invention as recited in claim 28, wherein, for step (e), the gain adjustment value is generated by the step of comparing the actual gain error with i) an upper bound and ii) a lower bound so as to adjust the gain adjustment value in discrete steps.

31. The invention as recited in claim 23, wherein, for step (c), the gain error information is the sum of the magnitudes of the samples corresponding to peaks in the detected data.

32. The invention as recited in claim 31, wherein the gain error information, $gi_m(k)$, at time k for the mth phase, τ_m, of sample sequence accounting for all B peaks spaced S_bT apart, S_b a positive integer, is:

$$gi_m(k) = \sum_{b=0}^{B-1} \left| y\left(kT + \tau_m - S_b Tb\right) \right|,$$

where $|\bullet|$ indicates "the absolute value of "•".

33. The invention as recited in claim 23, wherein, for step (d), the data is servo data including an address mark and encoded data.

34. The invention as recited in claim 33, wherein the address mark is a repeatable run out (RRO) address mark and encoded data is encoded RRO data.

35. The invention as recited in claim 23, wherein, for step (b), the distance measure is an absolute value distance between the portion of each sample sequence and an ideal sample sequence.

36. The invention as recited in claim 35, wherein step (b) comprises the step of determining the minimum of the summed absolute value distance between the portion of each sample sequence and an ideal sample sequence.

37. The invention as recited in claim 36, wherein step (b) comprises the step of determining the minimum of the summed absolute value distance $da_m(k)$ at time k as:

$$\min_{m,k} da_m(k) = \min_{m,k} \sum_{b=0}^{B-1} \left| y(kT + \tau_m - S_b Tb) - \hat{y}(kT - S_b Tb) \right|$$

where $y(\bullet)$ is either an observed sample or an interpolated sample, $\hat{y}(\bullet)$ is an ideal sample, B is a positive integer corresponding to a number of peaks, T is a symbol period, S_b is a separation of the bth peak sample from the prior peak sample ($0 \leq b \leq B$), and τ_m is a phase of either the read sample sequence or one of the interpolated sample sequences (m an integer, $0 \leq m \leq M$, and M a positive integer corresponding to the number of sample sequences).

38. The invention as recited in claim 35, wherein, for step (d), the minimum of the summed absolute value distance is selected when the minimum is less than a threshold value.

39. The invention as recited in claim 38, wherein, for step (d), either the minimum of the summed absolute value distance for a current time k or for a previous time k-1 is selected.

40. The invention as recited in claim 38, wherein the threshold value is selected based on a probability of error of detection.

41. The invention as recited in claim 23, wherein, for step (b), the distance measure is a minimum distance.

42. The invention as recited in claim 41, wherein, for step (b), the minimum distance is either minimum squared Euclidean distance or minimum absolute value distance.

43. The invention as recited in claim 23, wherein the method is embodied by a processor of an integrated circuit.

44. The invention as recited in claim 23, wherein the method is implemented by a processor in

a read channel component.

45. A computer-readable medium having stored thereon a plurality of instructions, the plurality of instructions including instructions which, when executed by a processor, cause the processor to implement a method for detecting data in a sample sequence read from a recording channel, the method comprising the steps of:

(a) generating one or more interpolated sample sequences from the read sample sequence, wherein each interpolated sample sequence has a different corresponding phase relative to the read sample sequence;

(b) generating a distance measure between a portion of each sample sequence and an ideal sample sequence, wherein the ideal sample sequence corresponds to peaks in the data;

(c) generating gain error information for the portion of each sample sequence;

(d) selecting either the read sample sequence or one of the interpolated sample sequences based on the minimum distance measures for use in detecting the data;

(e) generating a best gain error metric (GEM) for the selected sample sequence from the corresponding gain error information; and

(f) adjusting the read sample sequence based on the GEM.